JAPAN-USSR JOINT EMULSION CHAMBER EXPERIMENT AT PAMIR

JAPAN-USSR JOINT EXPERIMENT (I)

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Abstract

The results are presented for the systematic measurement of showers in the first carbon chamber of Japan-USSR joint experiment at Pamir. The intensity and the energy distribution of electromagnetic particles, of hadrons and of families are in good agreement with the results of other mountain experiment if we take into consideration the relative error in energy estimation.

1. Introduction.

Japan-USSR joint emulsion chamber experiment at Pamir plateau (4370m) has been continuing since 1981. The purpose of the experiment is a test for the future large scale emulsion chamber experiment to observe nuclear interaction at the energy region of $10^{16} \sim 10^{17}$ eV and is also to work as a interface among different emulsion chamber experiment of mountain altitude. In Table 1 we show the exposure list of joint chambers. The chamber 'Pamir-1' is for the energy calibration and it is found that upto the shower energy $\sim$20 TeV there are no appreciable difference of energy determination between in Soviet group and in Japanese group[1]. The present paper gives the results of systematic measurement of the first joint carbon chamber 'Pamir-2'.

2. Carbon chamber 'Pamir-2'.

The carbon chamber designed to observe hadron and gamma families consists of three parts, that is, Γ-block of 6 cmPb, H-block of 5 cmPb and carbon layer of 60 cm thick between the two. The effective thickness of the chamber is about 1.5 λ geo.. Fig.1 shows the basic structure of the carbon chamber. Two types of Japanese (SAKURA N-type and FUJI #100-type) and Soviet (PT6M-type and PTCШ-type) X-ray films are used as sensitive materials. About half, $\sim$33 m^2, of the chamber 'Pamir-2' has been systematically analysed[2].

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Table 1. Exposure list of joint chamber at Pamir (4370m)

chamber	area(m^2)	period (days)	type	sensitive layers	remarks
Pamir-1 81/82	11.2	253 Oct.'81 ~ June'82	flat 7 cmPb (calibration)	3 , 3*	[1]
Pamir-2 82/83	72.0	415 June'82 ~ Aug.'83	carbon chamber	2 , 3* in Γ-block 2 , 3* in H-block	present paper
	6.0	343 Aug.'82 ~ July'83	flat 6 cmPb (calibration)	2 , 3*	
Pamir-3 83/84	90.0	350 July'83 ~ July'84	carbon chamber	2 , 2* in Γ-block 2 , 2* in H-block	under analysis
	4.0		flat 7 cmPb (calibration)	5 , 5*	
Pamir-3' 83/85	~ 100	Oct.'83 ~	carbon chamber	2 in Γ-block 2 in H-block	under exposure
Pamir-4 84/85	~ 17	Aug.'84 ~	thick lead 50 cmPb		under exposure

*) number of sensitive layers of Soviet films.

3. Energy estimation.

Here we describe the procedure of Japanese group[2]. The detail procedure of Soviet group is described in Ref.[1,4]. The darkness of shower spot on X-ray films are measured by microphotometer with square slit of 200x200 μm^2. In this joint chamber, we have only two layers of Japanese X-ray films in each part of the chamber, Γ-block and H-block. Then we must estimate shower energy by using spot darkness on two layers of X-ray films except for the case that showers penetrate both Γ-block and H-block. The two different methods are applied. One (Method-I) is to use the following semi-empirical formula[2],

$$D_m^0 = D\max(D_{10}^{\Gamma}/D_8^{\Gamma})^{-\beta} \quad , \quad \beta=0.812-0.70\tan^2\theta$$

$$E = 10\cdot(D_m^0\sqrt{1+\tan^2\theta}/0.54)1.234$$

where D_8^{Γ} and D_{10}^{Γ} are darkness of a shower spot at 4 cmPb and 5 cmPb in Γ-block and Dmax is larger one between the two. θ is zenith angle of shower direction. For the showers(hadrons) observed in H-block, D_8^{Γ} and D_{10}^{Γ} are replaced with D_6^H and D_8^H, where D_6^H and D_8^H are darkness of a shower at 3 cmPb and 4 cmPb in H-block. The other (Method-II,[3]) is to estimate the shower maximum by fitting experimental points, only two points except for penetrating showers, with calculated shower transition curve. Above two methods were applied to the individual simulated cascade showers of gamma-ray primaries[5] and it is found that the average value has expected one though the relative error, ΔE/E, is rather large (20 ~30%). When the shower energy increases, $\gtrsim$ 50 TeV, Method-I gives underestimation (by ~20%) of the energy. The common shower spots are measured by Japanese group and by Soviet group. Fig.2 shows a correlation diagram on the energy of showers estimated by Soviet group and by Japanese group. As is seen in the figure there are no appreciable difference of energy estimation between the two.

4. Energy spectrum of (e,γ), of hadrons and of families.

Energy spectrum of (e,γ) Fig.4 shows integral energy spectrum of showers found in Γ-block. The spectra are expressed by the power function above energy 5 TeV. The Method-I gives steeper energy spectrum because of the underestimation of shower energy in high energy region. The straight line in the figure is a power function with index 2.0. Showers in Γ-block are mixture of electromagnetic showers and those from nuclear interaction of hadrons in Γ-block. About 20% of showers in Γ-block are considered as hadronic origin.

Energy spectrum of hadrons The visible energy spectrum of hadrons

constructed by showers observed in H-block is shown in Fig.3 by cross mark. The spectrum is also expressed by the power function with index 2.0 above energy 5TeV. The detection probability of hadrons in H-block is $\sim$33%. The spot darkness in H-block of hadronic showers becomes smaller because showers spread over during passage through the carbon layer, and then the visible energy is underestimated (by $\sim$20%). The flux of hadrons arriving at the chamber, indicated by broken line in the figure, is obtained by applying above two corrections. The relative ratio of intensity, $I_h/I_{e,\gamma}$, at the visible energy greater than 10 TeV, between hadrons and electromagnetic particles is about 2.

Energy specrrum of gamma-families Fig.5 shows integral energy spectrum of gamma-ray families. The spectrum is again well expressed by the power function with index 1.3, above total observed energy $\sim$ 20 TeV.

5. Comparison with the other experiment.

The relative error, $\Delta E/E$, in energy estimation affects the power index and the flux value of the energy spectrum. Suppose that the relative error in energy estimation has Gaussian type distribution with energy dependent dispersion $\sigma = \sigma_0(E/TeV)^{\delta}$ and spectrum is power type, then the ratio between the observed intensity, I, and the true one, I , is given by $I(>E)/I_0(>E) \simeq 1 + \varepsilon E^{2\delta}$. In the present experiment we have $\sigma_0 \sim 0.12$ and $\delta \sim 0.19$. Then we get $\varepsilon \sim 0.15$ under the assumption that power index of spectrum is 2.0. At the energy E=10TeV, observed intensity is considered $\sim$30% higher than the true one according to the above formula. The true intensity of (e,γ) is obtained by applying corrections for contamination of hadrons (20%) and for the effect of relative error in energy estimation (30%) to the observed intensity shown in Fig.3. Fig.6 shows the altitude dependence of the vertical flux of (e,γ) with energy greater than 10 TeV. As is seen in the figure, all experimental points are distributed around the expected exponential attenuation with $\Lambda_{att} \sim 120$ gr/cm^2. Thus we can conclude that there are no appreciable systematic difference of energy estimation between in the present experiment and in the other mountain experiments.

6. Discussions.

The relative error in energy estimation, by using two layers of X-ray films in the carbon chamber, is rather large, especially in high energy region. However, the vertical flux and the power index of spectra of electromagnetic particles, of hadrons and of families obtained in present measurement are not inconsistent with those of the other mountain experiment.

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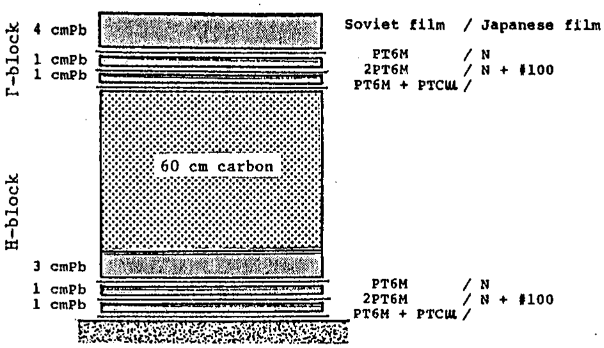

Fig.1 Basic structure of carbon chamber.

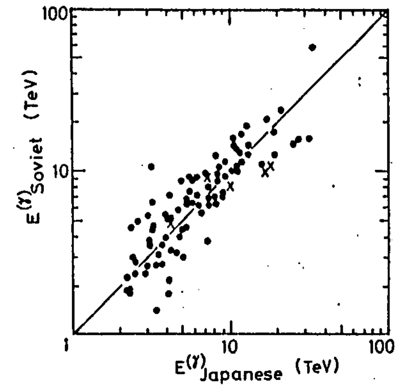

Fig.2 Correlation diagram on the shower energy estimated by Japanese group and by Soviet group. ●: (e,γ), X: hadrons

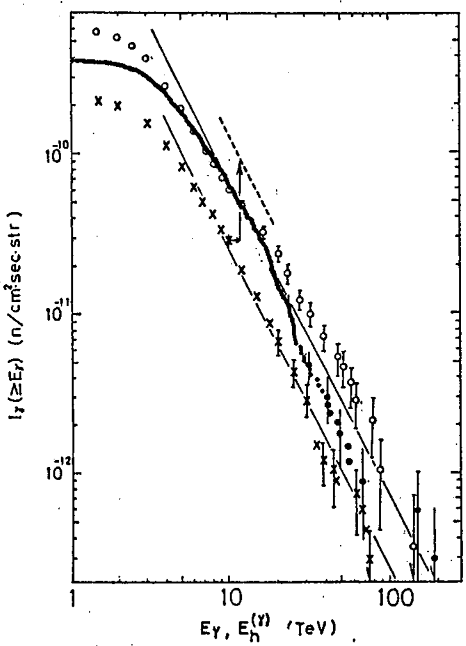

Fig.3 Integral energy spectra of (e,γ) and hadrons.
●: (e,γ) by Method-I
O: (e,γ) by Method-II
X: hadrons by Method-I
Lines are power function with index 2.0. Broken line is corrected spectrum of hadrons.

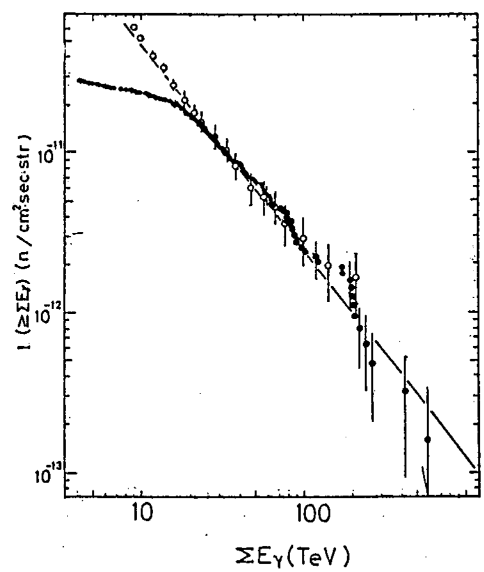

Fig.4 Integral energy spectrum of of gamma-ray families.
●: by Method-I
O: by Method-II

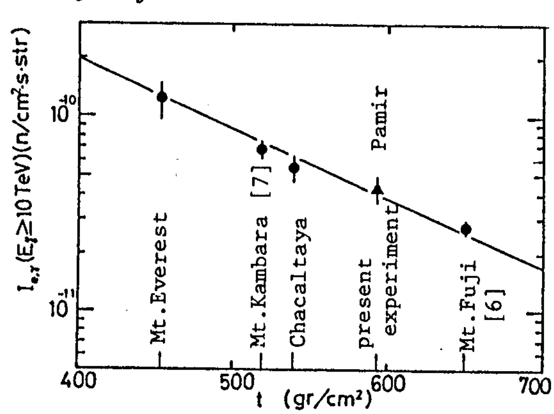

Fig.5 Vertical intensity of (e,γ) with energy greater than 10 TeV.